REMARKS

The Examiner's Action mailed on September 3, 2008, has been received and its contents carefully considered. Additionally attached to this Amendment is a Petition for a three-month Extension of Time extending the response period to March 3, 2009.

In this Amendment, Applicants have amended claim 5, and added claims 40-42. Claims 5 and 42 are the independent claims, and claims 5-6, 9-10, 18, 20, 37 and 39-42 are pending in the application. For at least the following reasons, it is submitted that this application is in condition for allowance.

The Examiner has objected to the Amendment to the Specification, asserting that the examples of "other materials" as previously disclosed have not been disclosed to be compounds, and in fact they are not (see the Action, page 3, lines 1-5). Applicants disagree with this assertion for the following reasons.

The original specification, at page 11, lines 6-13, recites, "Other materials, such as an aluminum-gallium indium phosphide $(Al_xGa_{1-x})_yIn_{1-y}P$, where $0 \leq x \leq 1$ and $0 \leq y \leq 1$, a gallium nitride (GaN), an aluminum gallium nitride (AlGaN), and an indium gallium nitride (InGaN), may also be employed." All of these materials (i.e., $(Al_xGa_{1-x})_yIn_{1-y}P$, GaN, AlGaN, InGaN) are described as compound semiconductors in the general dictionary.

For example, at "Template: III-V compounds" describing III-V compounds in the encyclopedia "Wikipedia", a copy of which is attached to this Amendment,

GaN is listed as one of the III-V **compounds** (see http://en.wikipedia.org/wiki/Template:III-V_compounds).

In addition, at "Compound semiconductor", Wikipedia describes, "a Compound Semiconductor is a semiconductor **compound** composed of elements from two or more different groups of periodic table. For e.g. **III-V semiconductors** composed of elements from group13 (B, Al, Ga, In) and from group 15 (N, P, As, Sb, Bi)." (see http://en.wikipedia.org/wiki/Compound_semiconductor). And, at "List of semiconductor materials", Wikipedia further describes that III-V **compounds** (i.e., III-V compound semiconductors) include GaN, AlGaN, and InGaN (see http://en.wikipedia.org/wiki/III-V_semiconductor).

Accordingly, All of the materials disclosed in the original specification (i.e., $(Al_xGa_{1-x})_yIn_{1-y}P$, GaN, AlGaN, InGaN) are included in III-V **compound** semiconductors, i.e., **compound** semiconductors composed of elements from group 13 (B, Al, Ga, In) and from group 15 (N, P, As, Sb, Bi).

The Examiner further states that none of the materials cited in the arguments are necessarily compounds, for which a definite ratio ordained by the valences of the atomic constituents would have to determine a fixed stoichiometric ratio. However, the ratio of the constituents of the compound semiconductor GaN can be basically expressed as a fixed ratio. For example, the ratio of constituents of the compound semiconductor GaN can be expressed as Ga:N = 1:1.

In addition, the ratio of the constituents of the compound semiconductor AlGaAs can be expressed as (Al+Ga):As = 1:1, because both Al and Ga belong to the III-B group in the periodic table (i.e., the number of the outermost electrons are the same between Al and Ga) and Al and Ga are replaceable by Ga and Al respectively. If the ratio of Ga in the compound semiconductor AlGaAs is decreased, the ratio of Al in the compound semiconductor AlGaAs must be increased. The reason why Al and Ga are replaceable by Ga and Al respectively is that Al and Ga have similar chemical characteristic, but they are different elements having different energy levels respectively and the ratio of Al and Ga in the LED is changed in order to change the wavelength of light emitted from the LED. The ratio of Al and Ga can be freely changed as long as the sum total of the ratio of Al and the ratio of Ga is 1. This is expressed by the subscripts "1-x" and "x" of the chemical formula (i.e., $Al_xGa_{1-x}As$), where "1-x" plus "x" equals 1. The same applies to other compound semiconductors.

In Wikipedia, Indium gallium nitride (InGaN) is also expressed by $In_xGa_{1-x}N$ (see http://en.wikipedia.org/wiki/ Indium_gallium_nitride), indicating that the ratio of (In+ Ga):N = 1:1. Similarly, the ratio of constituents of the compound semiconductor AlGaN can be expressed as (Al+Ga):N = 1:1.

The same applies to the more complicated compound semiconductor AlGaInP. In this case, since all of Al, Ga, and In are the III-B group elements, Al, Ga, and In are replaceable by any of Al, Ga, and In, and the ratio of constituents

of the compound semiconductor AlGaInP can be expressed as (Al+Ga+In):N = 1:1.

The Examiner further asserts that the term "inorganic" introduces new matter (see the Action, page 3, lines 8 and 9). Referring to Wikipedia, an **organic** compound is any member of a large class of chemical compounds whose molecules contain carbon (see http://en.wikipedia.org/wiki/Organic_compound). However, $(Al_xGa_{1-x})_yIn_{1-y}P$, GaN, AlGaN and InGaN do <u>not</u> include carbon element "C" and thus are **inorganic**.

Therefore, all of the examples of "other materials" disclosed in the original specification are **inorganic compound**. It is thus requested that the Examiner's objection to the specification be withdrawn.

The Examiner has further rejected claims 5-6, 9-10, 18, 20, 37 and 39 under 35 U.S.C. 112, first paragraph as failing to comply with the written description requirements and under 35 U.S.C. 112 second paragraph as being indefinite, because of the newly introduced limitation "*inorganic compound.*" However, this feature (i.e., "*inorganic compound*") was described in and supported by the original specification at least for the same reasons presented above in response to the Examiner's objection, and thus the claims including this feature are not indefinite. It is thus requested that the Examiner's rejections based on the limitation "*inorganic compound*" be withdrawn.

The Examiner has further rejected claims 5-6, 9-10, 18, 20, 37 and 39 under 35 U.S.C. 112, first paragraph as failing to comply with the written

description requirements and under 35 U.S.C. 112 second paragraph as being indefinite, because of the newly introduced limitation "said semiconductor thin film being disposed so as not to extend outward from edges of the metal layer." In response, independent claim 5 has been amended to delete this specific limitation criticized by the Examiner, rendering the Examiner's rejections of the claims based on such a limitation moot.

The Examiner has rejected claims 5 and 37 as being obvious over *Kub et al.* (USP 6,242,324) (hereafter simply *Kub*). It is submitted that these claims are clearly patentable over the cited references for at least the following reasons.

Independent claim 5 is directed to a semiconductor apparatus that includes a silicon substrate, a planarized region defined over the silicon substrate, a metal layer disposed over the planarized region, and at least one semiconductor thin film.

Claim 5 has been amended to recite that the semiconductor thin film is made from **other** process (which is supported by Applicants' Figures 7-11), disposed over said metal layer, each semiconductor thin film being made to be small enough to include a single light-emitting element (which is supported by the specification, page 19, lines 25 and 26, page 18, line 10, and Applicants' Figure 13), and being bonded on the metal layer, so that each semiconductor thin film is disposed above the integrated circuit and said metal layer electrically connects said light-emitting element to the integrated circuit. The semiconductor thin film is made of an inorganic compound semiconductor as a main material.

Due to such features, the present invention has an advantageous effect that at least one semiconductor thin film as a very thin film can be strongly bonded on the planar metal layer.

Furthermore, since the semiconductor thin films are made of inorganic compounds, and each semiconductor thin film is small enough to have a single light emitting element, the heat stress resulting from the difference of the heat expansion coefficients between the silicon substrate and the compound semiconductor can be reduced. Since the inorganic compound material has greater heat-resisting property than the organic compound material, the use of the inorganic compound material is suitable to application of a printer and so on, the inside of which is heated to high temperature.

In *Kub*, the monocrystalline silicon layer 50 and the lattice-alignment flexible silicon layer 40 and 58 are disposed on the metal layer 38 and 54. However, these silicon layers 40, 50/58 do not have a function of passive element such as a light emitting element. These layers 40, 50/58 are different from and separated from multilayer film of CdTe material 44 or 64 and HgCdTe material 46 or 66, and thus do not include the photodetector material 44, 64, 46, 66. Thus, these silicon layers 40, 50/58 are only buffer layers that has nothing to do with light-emitting function or photodetecting function. Further, there is no disclosure or suggestion that the layers 40, 50/58 include any light-emitting element. Therefore, layers 40, 50/58 are not equivalent to the claimed semiconductor thin film that includes light-emitting element.

Alternatively, even assuming that the semiconductor thin film of the present invention corresponds to *Kub*'s light receiving element comprising a multilayer film of CdTe material 44 or 64 and HgCdTe material 46 or 66, since this multilayer film needs to be disposed on the lattice-matched flexible silicon layer 40 or 66, it is not a film made in **another** process and bonded on the silicon layer. Rather, *Kub*'s multilayer film of CdTe material 44 or 64 and HgCdTe material 46 or 66 must be formed on the silicon layer so as to lattice-match the silicon layer 40 or 66. Kub also states that CdTe/HgCdTe material 44, 46 is **grown** on the thin compliant semiconductor layer (see col. 9, line 65).

In contrast, the claimed semiconductor thin film to be bonded to the silicon substrate is made from **other** process. Thus, the present invention has an advantageous effect that no complicated process is needed after the semiconductor film is bonded on the silicon substrate.

Accordingly, *Kub* clearly does not disclose or even suggest a semiconductor thin film, as recited in amended claim 5. It is thus submitted that claim 5 and claim 37 depending therefrom are clearly patentable over the cited reference.

The Examiner's Action has rejected claims 9, 10 and 18 as being obvious over *Kub* in view of *Walsh* (US 6,351,327) or *Tohyama et al.* (US 6,433,367). The Examiner's Action has further rejected claim 20 as being obvious over *Kub* in view of *Tohyama et al.* (US 6,433,367). The Examiner's Action has further rejected

claims 39 and 6 as being obvious over *Kub* in view of *Ferra et al.* (US 2002/0155795). However, none of *Walsh, Tohyama et al. and Ferra et al.* overcome the above noted deficiencies of *Kub*. Thus, claims 9, 10, 18, 20, 39 and 6 depending from independent claim 5 are *prima facie* patentable over the cited references for at least the same reasons that independent claim 5 is patentable.

New claim 40 has been added. Claim 40 is supported by the specification, at pages 10 and 11. Because claim 40 depends from independent claim 5, it is submitted that claim 40 is *prima facie* patentable over the cited references for at least the same reasons as independent claim 5, as well as for the additional features claim 5 recites.

New claim 41 has been added. Claim 41 is supported by the specification, at page 9, lines 24-26, page 18, line 18 and Applicants' Figure 15. Because claim 41 depends from independent claim 5, it is submitted that claim 40 is *prima facie* patentable over the cited references for at least the same reasons as independent claim 5.

In addition, claim 41 further recites that the light-emitting element is in direct contact with the metal layer. However, *Kub* does not disclose or suggest that an LED element is in direct contact with a metal layer, as would be required by claim 41. Rather, in *Kub*'s Figure 3, other layers 40 and 42 are disposed between the CdTe material layer 44 and the metal layer 38, and in *Kub*'s Figure 5, other layers 58 and 50 are disposed between the CdTe material layer 64 and the metal layer

54. Thus, *Kub's* CdTe material layer 44 or 64 is spaced apart from the metal layer 38 or 54, rather than being in direct contact therewith.

New claim 42 has been added. Claim 42 is directed to a method of fabricating a combined semiconductor apparatus. Claim 42 recite, **after forming each semiconductor thin film with the light-emitting element**, disposing each semiconductor thin film over said metal layer, and bonding each semiconductor thin film on the metal layer, so that **light-emitting element is in contact with the metal layer**, which are similarly recited in claim 5 and claim 41. Thus, claim 42 is is *prima facie* patentable over the cited references for at least the same reasons as claim 5 and claim 41.

Based on the above, it is submitted that this application is in condition for allowance and such a Notice, with allowed claims 5-6, 9-10, 18, 20, 37 and 39-42, earnestly is solicited.

Should the Examiner feel that a conference would help to expedite the prosecution of the application, the Examiner is hereby invited to contact the undersigned counsel to arrange for such an interview.

An extension of time fee are submitted herewith. Should the remittance be accidentally missing or insufficient, or should any additional fees be requested, the Commissioner is hereby authorized to charge such fees to our deposit No. 18-0002, and is requested to advise us accordingly.

Respectfully submitted,

March 3, 2009
Date

Jun-Hwa Jeong
Limited Recognition. No. L0471
RABIN & BERDO, PC - Cust. No. 23995
Facsimile: 202-408-0924
Telephone: 202-371-8976

JJ/ng

Template:III-V compounds

'III-V' compounds (Binary)	5 B	13 Al	31 Ga	49 In	81 Tl
7 N	BN	AlN	GaN	InN	TlN
15 P	BP	AlP	GaP	InP	TlP
33 As	BAs	AlAs	GaAs	InAs	TlAs
51 Sb	BSb	AlSb	GaSb	InSb	TlSb
84 Bi	BBi	AlBi	GaBi	InBi	TlBi
Key for above table:	**Nonmetals**	**Metalloids**	**Poor metals**	atomic number in black above element	

II　元素の周期表　(a) 長周期型

数字は原子番号

族 / 周期	1 A	2 A	3 A	4 A	5 A	6 A	7 A	8			1 B	2 B	3 B	4 B	5 B	6 B	7 B	0
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57~71*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89~103**															

*ランタノイド	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
**アクチノイド	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

List of semiconductor materials

(Redirected from III-V semiconductor)

Semiconductor materials are insulators at absolute zero temperature that conduct electricity in a limited way at room temperature. The defining property of a semiconductor material is that it can be doped with impurities that alter its electronic properties in a controllable way.

Because of their application in devices like transistors (and therefore computers) and lasers, the search for new semiconductor materials and the improvement of existing materials is an important field of study in materials science.

The most commonly used semiconductor materials are crystalline inorganic solids. These materials can be classified according to the periodic table groups from which their constituent atoms come.

List of semiconductor materials

Contents [hide]

Group IV [edit]

- Group IV elemental semiconductors
  - Diamond (C)
  - Silicon (Si)
  - Germanium (Ge)
- Group IV compound semiconductors
  - Silicon carbide (SiC)
  - Silicon germanide (SiGe)

Group III-V [edit]

- III-V semiconductors (*See also:* Template:III-V compounds)
  - Aluminium antimonide (AlSb)
  - Aluminium arsenide (AlAs)
  - Aluminium nitride (AlN)
  - Aluminium phosphide (AlP)
  - Boron nitride (BN)
  - Boron phosphide (BP)
  - Boron arsenide (BAs)
  - Gallium antimonide (GaSb)
  - Gallium arsenide (GaAs)

navigation
- Main page
- Contents
- Featured content
- Current events
- Random article

search
Go Search

interaction
- About Wikipedia
- Community portal
- Recent changes
- Contact Wikipedia
- Donate to Wikipedia
- Help

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link
- Cite this page

languages
- Español
- 中文

        - Gallium nitride (GaN)
        - Gallium phosphide (GaP)
        - Indium antimonide (InSb)
        - Indium arsenide (InAs)
        - Indium nitride (InN)
        - Indium phosphide (InP)
    - III-V ternary semiconductor alloys
        - Aluminium gallium arsenide (AlGaAs, $Al_xGa_{1-x}As$)
        - Indium gallium arsenide (InGaAs, $In_xGa_{1-x}As$)
        - Indium gallium phosphide (InGaP)
        - Aluminium indium arsenide (AlInAs)
        - Aluminium indium antimonide (AlInSb)
        - Gallium arsenide nitride (GaAsN)
        - Gallium arsenide phosphide (GaAsP)
        - Aluminium gallium nitride (AlGaN)
        - Aluminium gallium phosphide (AlGaP)
        - Indium gallium nitride (InGaN)
        - Indium arsenide antimonide (InAsSb)
        - Indium gallium antimonide (InGaSb)
    - III-V quaternary semiconductor alloys
        - Aluminium gallium indium phosphide (AlGaInP, also InAlGaP, InGaAlP, AlInGaP)
        - Aluminium gallium arsenide phosphide (AlGaAsP)
        - Indium gallium arsenide phosphide (InGaAsP)
        - Aluminium indium arsenide phosphide (AlInAsP)
        - Aluminium gallium arsenide nitride (AlGaAsN)
        - Indium gallium arsenide nitride (InGaAsN)
        - Indium aluminium arsenide nitride (InAlAsN)
        - Gallium arsenide antimonide nitride (GaAsSbN)
    - III-V quinary semiconductor alloys
        - Gallium indium nitride arsenide antimonide (GaInNAsSb)
        - Gallium indium arsenide antimonide phosphide (GaInAsSbP)

Group II-VI [edit]

- II-VI semiconductors
    - Cadmium selenide (CdSe)
    - Cadmium sulfide (CdS)
    - Cadmium telluride (CdTe)
    - Zinc oxide (ZnO)
    - Zinc selenide (ZnSe)
    - Zinc sulfide (ZnS)
    - Zinc telluride (ZnTe)
- II-VI ternary alloy semiconductors
    - Cadmium zinc telluride (CdZnTe, CZT)
    - Mercury cadmium telluride (HgCdTe)
    - Mercury zinc telluride (HgZnTe)
    - Mercury zinc selenide (HgZnSe)

Group I-VII [edit]

- I-VII semiconductors
  - Cuprous chloride (CuCl)

Group IV-VI [edit]

- IV-VI semiconductors
  - Lead selenide (PbSe)
  - Lead sulfide (PbS)
  - Lead telluride (PbTe)
  - Tin sulfide (SnS)
  - Tin telluride (SnTe)
- IV-VI ternary semiconductors
  - lead tin telluride (PbSnTe)
  - Thallium tin telluride (Tl_2SnTe_5)
  - Thallium germanium telluride (Tl_2GeTe_5)

Group V-VI [edit]

- V-VI semiconductors
  - Bismuth telluride (Bi_2Te_3)

Group II-V [edit]

- II-V semiconductors
  - Cadmium phosphide (Cd_3P_2)
  - Cadmium arsenide (Cd_3As_2)
  - Cadmium antimonide (Cd_3Sb_2)
  - Zinc phosphide (Zn_3P_2)
  - Zinc arsenide (Zn_3As_2)
  - Zinc antimonide (Zn_3Sb_2)

Layered semiconductors [edit]

-
  - Lead(II) iodide (PbI_2)
  - Molybdenum disulfide (MoS_2)
  - Gallium Selenide (GaSe)
  - Tin sulfide (SnS)
  - Bismuth sulfide (Bi_2S_3)

Others [edit]

-
  - Copper indium gallium selenide (CIGS)
  - Platinum silicide (PtSi)
  - Bismuth(III) iodide (BiI_3)
  - Mercury(II) iodide (HgI_2)
  -

- Miscellaneous oxides
  - Titanium dioxide: anatase (TiO_2)
  - Copper(I) oxide (Cu_2O)
  - Copper(II) oxide (CuO)
  - Uranium dioxide (UO_2)
  - Uranium trioxide (UO_3)
- Organic semiconductors
- Magnetic semiconductors

See also [edit]

- Heterojunction

Category: Semiconductor materials

Compound semiconductor

This article is **in need of attention from an expert on the subject**. WikiProject Chemistry or the Chemistry Portal may be able to help recruit one. *(November 2008)*

A **Compound Semiconductor** is a semiconductor compound composed of elements from two or more different groups of the periodic table. For e.g. III-V (or 13-15) semiconductors are composed of elements from group 13 (B, Al, Ga, In) and from group 15 (N, P, As, Sb, Bi). The range of possible formulae is quite broad because these elements can form binary (two elements, e.g. GaAs), ternary (three elements, e.g. InGaAs) and quaternary (four elements, e.g. AlInGaP). See the list of semiconductor materials for compound families and examples.

Fabrication: [edit]

Metalorganic Vapor Phase Epitaxy or MOVPE is the most popular deposition technology for the formation of compound semiconducting thin films for devices. It uses ultrapure metalorganics and/or hydrides as precursors source materials in an ambient gas such as hydrogen.

Other techniques of choice are Molecular Beam Epitaxy (MBE), Hydride Vapour Phase Epitaxy (HVPE), Liquid Phase Epitaxy (LPE), Metalorganic Molecular Beam Epitaxy (MOMBE) and Atomic Layer Deposition (ALD), etc.

An interesting online resource for compound semiconductors and their fabrication, (Britney's Guide to Semiconductor Physics), is also available as reference material for semiconductor scientists and non-scientists.

Category: Semiconductors

navigation
- Main page
- Contents
- Featured content
- Current events
- Random article

search

Go Search

interaction
- About Wikipedia
- Community portal
- Recent changes
- Contact Wikipedia
- Donate to Wikipedia
- Help

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link
- Cite this page

languages
- 日本語

Aluminium gallium arsenide

Aluminium gallium arsenide (also **aluminum gallium arsenide**) ($Al_xGa_{1-x}As$) is a semiconductor material with very nearly the same lattice constant as GaAs, but a larger bandgap. The *x* in the formula above is a number between 0 and 1 - this indicates an arbitrary alloy between GaAs and AlAs.

The bandgap varies between 1.42 eV (GaAs) and 2.16 eV (AlAs). For $x < 0.4$, the bandgap is direct.

The formula *AlGaAs* should be considered an abbreviated form of the above, rather than any particular ratio.

Aluminium gallium arsenide is used as a barrier material in GaAs based heterostructure devices. The AlGaAs layer confines the electrons to a gallium arsenide region. An example of such a device is a quantum well infrared photodetector (QWIP).

Safety and toxicity aspects [edit]

The toxicology of AlGaAs has not been fully investigated. The dust is an irritant to skin, eyes and lungs. The environment, health and safety aspects of aluminium gallium arsenide sources (such as trimethylgallium and arsine) and industrial hygiene monitoring studies of standard MOVPE sources have been reported recently in a review [1].

References [edit]

1. ^ Journal of Crystal Growth (2004); doi:10.1016/j.jcrysgro.2004.09.007

External links [edit]

- Extensive site on the physical properties of aluminium gallium arsenide

Categories: Arsenides | Aluminium compounds | Gallium compounds | Semiconductor materials | III-V compounds

navigation
- Main page
- Contents
- Featured content
- Current events
- Random article

search

Go Search

interaction
- About Wikipedia
- Community portal
- Recent changes
- Contact Wikipedia
- Donate to Wikipedia
- Help

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link
- Cite this page

languages
-
- Deutsch
- Español
- Français

Aluminium gallium nitride

(Redirected from AlGaN)

Aluminium gallium nitride (AlGaN) is a semiconductor material. It is an alloy of aluminium nitride and gallium nitride.

AlGaN is used to manufacture light-emitting diodes operating in blue to ultraviolet region, where wavelengths down to 250 nm (far UV) were achieved. It is also used in blue semiconductor lasers. It is also used in detectors of ultraviolet radiation, and in AlGaN/GaN HEMT transistors.

AlGaN is often used together with gallium nitride or aluminium nitride, forming heterojunctions.

AlGaN layers can be also grown on sapphire.

Safety and toxicity aspects [edit]

The toxicology of AlGaN has not been fully investigated. The AlGaN dust is an irritant to skin, eyes and lungs. The environment, health and safety aspects of aluminium gallium nitride sources (such as trimethylgallium and ammonia) and industrial hygiene monitoring studies of standard MOVPE sources have been reported recently in a review [1].

References [edit]

1. ^ Environment, health and safety issues for sources used in MOVPE growth of compound semiconductors; D V Shenai-Khatkhate, R Goyette, R L DiCarlo and G Dripps, Journal of Crystal Growth, vol. 1-4, pp. 816-821 (2004); doi:doi:10.1016/j.jcrysgro.2004.09.007

External links [edit]

Categories: Semiconductor materials | Aluminium compounds | Gallium compounds | Nitrides | III-V compounds | Light-emitting diodes

navigation
- Main page
- Contents
- Featured content
- Current events
- Random article

search

Go Search

interaction
- About Wikipedia
- Community portal
- Recent changes
- Contact Wikipedia
- Donate to Wikipedia
- Help

toolbox
- What links here
- Related changes
- Upload file
- Special pages
- Printable version
- Permanent link
- Cite this page

languages

Indium gallium nitride

Indium gallium nitride (**InGaN**, $In_xGa_{1-x}N$) is a semiconductor material made of a mix of gallium nitride (GaN) and indium nitride (InN). It is a ternary group III/group V direct bandgap semiconductor. Its band gap can be tuned by varying the amount of indium in the alloy. The ratio of In/Ga is usually between 0.02/0.98 and 0.3/0.7.

Indium gallium nitride is the light-emitting layer in modern blue and green LEDs and often grown on a GaN buffer on a transparent substrate as, e.g. sapphire or silicon carbide. It has a high heat capacity and its sensitivity to ionizing radiation is low (like other group III nitrides), making it also a potentially suitable material for solar cell arrays for satellites.

It is theoretically predicted that in a composition regime between ~ 15% -85% Indium nitride spinodal decomposition should occur leading to In-rich and Ga-rich InGaN regions or clusters. However, local structure studies of InGaN did not show any evidence for strong phase segregation, despite signs of a weak phase segregation being observed [1].

GaN is a non-defect rich material with typical dislocation densities exceeding 10^8 cm^{-2}. Light emission from InGaN layers grown on such GaN buffers used in blue and green LEDs is expected to be low because of non-radiative recombination at such defects. Nevertheless InGaN quantum wells, are efficient light emitters in green, blue, white and ultraviolet light-emitting diodes and diode lasers. In the indium-rich regions, with a lower bandgap than the surrounding material, most electron-hole pairs recombine and by the lower potential energy of these clusters carriers are hindered to diffuse and recombine non-radiatively at crystal defects.

The wavelength emitted, dependent on the material's band gap, can be controlled by the GaN/InN ratio, from near ultraviolet for 0.02In/0.98Ga through 390 nm for 0.1In/0.9Ga, violet-blue 420 nm for 0.2In/0.8Ga, to blue 440 nm for 0.3In/0.7Ga, to red for higher ratios and also by the thickness of the InGaN layers which are typically in the range of 2-3 nm.

This defect tolerance, together with a good spectral match to sunlight, also makes the material suitable for solar cells. It is possible to grow multiple layers with different bandgaps, as the material is relatively insensitive to defects introduced by a lattice mismatch between the layers. A two-layer multijunction cell with bandgaps of 1.1 eV and 1.7 eV can attain a theoretical 50% maximum efficiency, and by depositing multiple layers tuned to a wide range of bandgaps an efficiency up to 70% is theoretically expected.[2]

Quantum heterostructures are often built from GaN with InGaN active layers.

InGaN is often used together with other materials, eg. GaN, AlGaN, on SiC, sapphire and even silicon etc.

Contents [hide]

Safety and toxicity aspects [edit]

The toxicology of InGaN has not been fully investigated. The dust is an irritant to skin, eyes and lungs. The environment, health and safety aspects of indium gallium nitride sources (such as trimethylindium, trimethylgallium and ammonia) and industrial hygiene monitoring studies of

See also [edit]

- Indium gallium phosphide
- Indium gallium arsenide
- Shuji Nakamura

References [edit]

1. ^ V. Kachkanov, K.P. O'Donnell, S. Pereira, R.W. Martin, Phil. Mag. 87(13), 1999–2017 (2007)
2. ^ A nearly perfect solar cell, part 2
3. ^ Environment, health and safety issues for sources used in MOVPE growth of compound semiconductors; D V Shenai-Khatkhate, R Goyette, R L DiCarlo and G Dripps, Journal of Crystal Growth, vol. 1-4, pp. 816-821 (2004); doi:doi:10.1016/j.jcrysgro.2004.09.007

External links [edit]

Categories: Indium compounds | Gallium compounds | Nitrides | Semiconductor materials | III-V compounds | Light-emitting diodes